Dune Groundwater

Planning & Management Considerations

For The Oregon Coast

Oregon Coastal Zone Management Association, Inc.

Oregon Coastal Zone Management Program W.P.

This report was prepared as part of a larger document addressing various beach and dune planning and management considerations and techniques. Other segments of the document and additional materials are:

I. BACKGROUND ON BEACH AND DUNE PLANNING:

Background of the Study

An Introduction to Beach and Dune Physical and Biological Processes

Beach and Dune Planning and Management on the Oregon Coast: A Summary of the State-of-the-Arts

II. BEACH AND DUNE IDENTIFICATION:

A System of Classifying and Identifying Oregon's Coastal Beaches and Dunes

III. PHYSICAL AND BIOLOGICAL CONSIDERATIONS:

Physical Processes and Geologic Hazards on the Oregon Coast

Critical Species and Habitats of Oregon's Coastal Beaches and Dunes

IV. MANAGEMENT CONSIDERATIONS:

Dune Groundwater Planning and Management Considerations for the Oregon Coast

Off-road Vehicle Planning and Management on the Oregon Coast

Sand Removal Planning and Management Considerations for the Oregon Coast

Oregon's Coastal Beaches and Dunes: Uses, Impacts and Management Considerations

Dune Stabilization and Restoration: Methods and Criteria

V. IMPLEMENTATION TECHNIQUES:

Beach and Dune Implementation Techniques: Findings-of-Fact

Beach and Dune Implementation Techniques: Site Investigation Reports

*Beach and Dune Implementation Techniques: Model Ordinances**

VI. ANNOTATED BIBLIOGRAPHY:

Beach and Dune Planning and Management: An Annotated Bibliography

VII. EDUCATIONAL MATERIALS:

Slide show: *Managing Oregon's Beaches and Dunes*

Brochure: *Planning and Managing Oregon's Coastal Beaches and Dunes*

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DUNE GROUNDWATER PLANNING AND MANAGEMENT CONSIDERATIONS FOR THE OREGON COAST

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PREFACE

The following report presents the results of an overview of groundwater planning and management considerations necesssary in beach and dune areas as conducted by the Oregon Coastal Zone Management Association, Inc. This report constitutes one element of an overall analysis of planning for, and managing, coastal beaches and dunes as required by Oregon's Beaches and Dunes Goal.

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I. SAND DUNE GROUNDWATER CHARACTERISTICS

Groundwater is that water beneath the earth's surface which is contained in pore spaces within the soil and rock. It is critical to acquire an adequate picture of groundwater characteristics before developing areas underlain by immense quantities of sand such as those which exist along the Oregon coast. Sand deposits are comparatively porous and thus downward percolation is quite rapid. Because of that potential, hazards associated with the development of this region include, for example, drawdown, saltwater intrusion and surface and groundwater pollution.

Groundwater exists as a large coherent body of water (or aquifer) which underlies dune sands. The boundaries of the groundwater are formed by underlying bedrock and relatively impervious terrace deposits, bedrock margins exposed at the surface (i.e. the basal western slopes of the Coast Range), and the ocean to the west, (see Figure 1). Impermeable silt and clay lenses are found within the deeper parts of the sand deposits which oftentimes restrict the vertical movement of water.

The top surface of the zone of groundwater is the water table. The general shape of the water table is a subdued replica of the land surface. It is farthest from the surface under the larger oblique-ridge dunes and closest at topographic lows. Most surface water (lakes, streams and marshes) is a surface expression of this water table occurring where the land surface dips to intersect the water table. Locally, "perched" water tables may exist. These are created by discontinuous bodies of impermeable materials located beneath the land surface but higher than the main water table. This impermeable layer catches and holds the water reaching it from above. On the western margin of the aquifer, the position of the freshwater/saltwater margin is not clearly understood but it most commonly appears to extend somewhat seaward of the beach.

The water table reflects a seasonal variation, being higher in the winter recharge months and lower in the summer. Recharge of dune aquifers occurs primarily from infiltrating precipitation. It is estimated that fully 75 to 80 percent of the 50 to 70 inches of annual precipitation received on the Oregon coast reaches the groundwater. The remainder is lost through surface runoff in streams, evaporation and plant use. Most of the groundwater eventually seeps directly into the ocean under the beach. Locally, lesser amounts enter lakes and streams especially during recharge months. Throughout the year the interaction between the lakes, streams and the water table appears to be one of mutual dependence. During summer months the water table may be lowered from three to ten feet, at which time it appears that lakes may discharge water back to the water table.

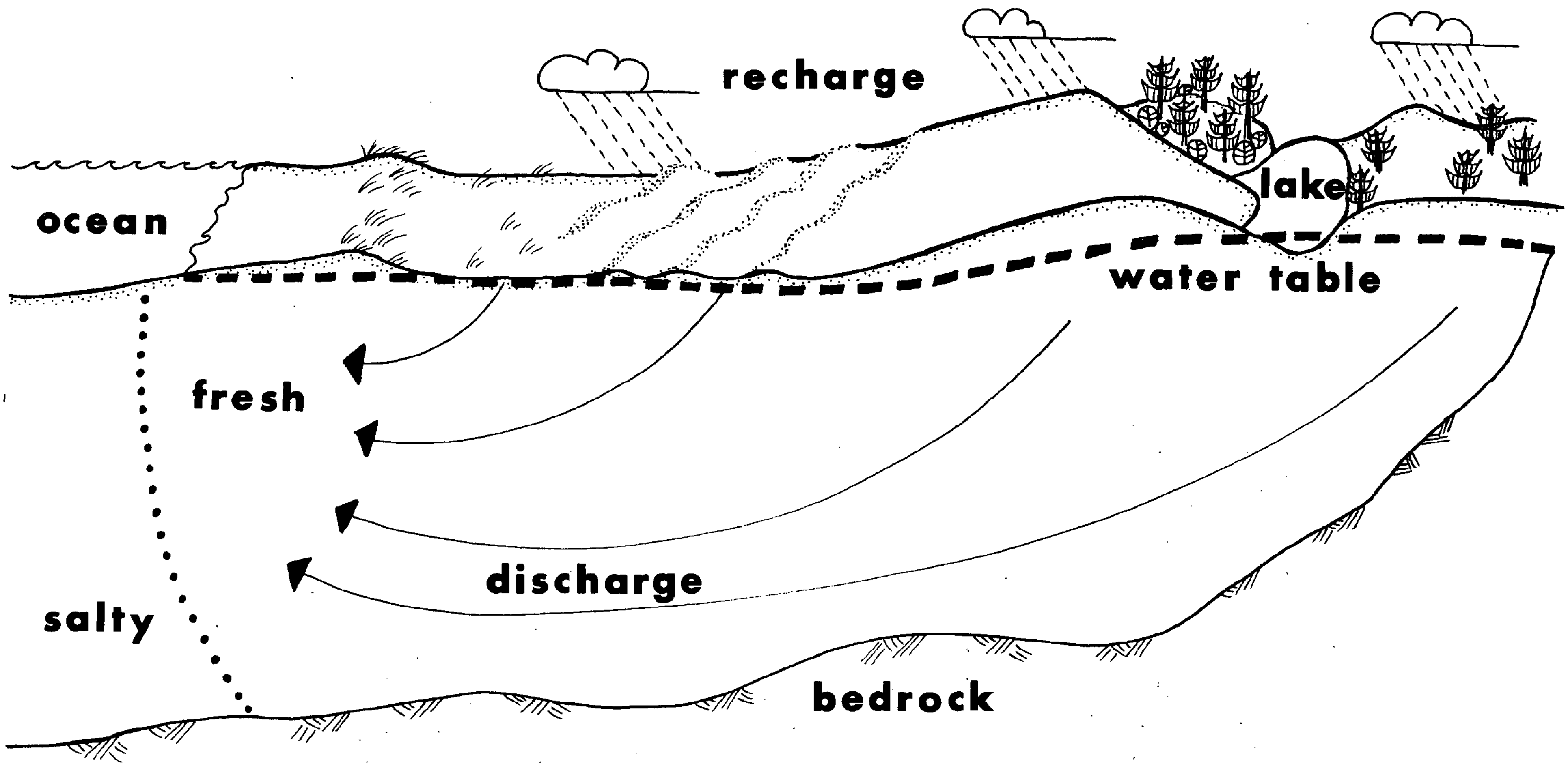

Figure 1. Schematic illustration of groundwater interactions common to coastal beach and dune areas indicates the cycle of discharge and recharge and the confines of groundwater between bedrock and the surface (source: U.S.G.S. unpublished materials).

Three larger dune areas, the Clatsop Plains and the Florence and Coos Bay dune sheets, appear to possess complete groundwater flow systems. That is the groundwater flow operates as an exclusive unit within the sand deposit and has little or no interaction with groundwater outside its own boundaries. A system may contain more than one subbasin. Groundwater moves relatively slowly both down gradient and from recharge to discharge zones. Rate of flow varies from site to site but is estimated to be five to seventeen feet per day in the Clatsop dune aquifer (Sweet, 1977, p. 11).

The chemical quality of the groundwater is generally good except for local problems with acidity. At a number of sites, high levels of dissolved iron and nitrate-nitrogen concentrations exist. These result naturally from chemical activities associated with the decomposition of vegetation in bog and marsh areas (Sweet, p. 16 and 18; Luzier, 1978).

II. GROUNDWATER HAZARD TYPES

Hazards and problems associated with the dune groundwater include high water table, ponding, saltwater intrusion, water table drawdown and pollution. It should be pointed out that hazards exist only in relation to man's use of a site. Any sites suspected of exhibiting hazard characteristics should be further investigated in light of the projected use for the area.

A. High Water Table

A high water table technically occurs at any surface intersection of the groundwater such as a lake, stream or marsh. However, those high groundwater areas associated with hazard are most commonly sites of extremely flat topography or depressions which contain water only part of the year. These sites exhibit standing water anywhere from a few weeks to eight months or more. They may be recognized in the drier summer months by the presence of such features as marshy ground, reeds, marsh grasses, soil with a high organic content and a black to gray or blue-gray color, sometimes accompanied by a strong organic aroma.

1. Potential sites

Those sand dune landforms most susceptible to the incidence of high water table problems include:

a. All deflation plains

This includes both the presently "active" forms which are situated on the lee side of the foredune and the historically active forms which are now found considerably inland from the present foredune area. These exhibit a flat surface topography, are usually forested and the water table is at or near the surface most of the year.

b. The border zone between the deflation plain and interior dunes

Both interior hummock dunes and transverse-ridge dunes irregularly interface with the deflation plain on their western border. These sites would be susceptible to high water table problems in their basal portions. They can often be recognized by the presence of marsh vegetation or surface water between dunes.

c. The fringes of mostly permanent waterbodies

The areas surrounding intersections of the groundwater table are likely to possess high water table levels themselves. This is because: (1) the water table follows the general slope of the land, (2) it fluctuates during the year and (3) because the area may be subject to flooding.

d. Occasionally wet interdune area

This includes topographic lows between dunes of any form but primarily the larger oblique-ridge and the commonly forested surface-stabilized and older stable dunes. These may exhibit mottled gray-blue soils and/or marsh vegetation.

2. Potential impacts and management techniques

Developmental activities in areas of seasonally high groundwater can incur such impacts as the flooding of surface and subsurface facilities, flotation and failure of buoyant buried structures such as pipelines and septic tanks, differential settlement of larger structures, construction and excavation difficulties, surface and groundwater contamination, destruction of valuable fish and wildlife habitat, and heightened earthquake impact.

In order to avoid such problems, certain development criteria should be adhered to. Developments should be restricted to those forms of land use which are either compatable with the characteristics of the site or which can be built to provide adequate safety and minimize impacts on the water resources. Structures, roads and sewage disposal systems should be set well above the winter high water table and well back from any water bodies. The alteration of wetlands by dredging or filling should be avoided where possible in order that the system's unique productivity and water retention capabilities will not be diminished.

Engineering studies should be undertaken particularly for any linear developments, such as pipelines and roads, which must span high water table areas. The use of pilings and drainage tiles and culverts are commonly recommended in such areas.

B. Ponding

Ponding occurs in low, poorly drained sites where excess precipitation or flood waters accumulate. Topographic restrictions and/or poor soil and bedrock permeability disallow runoff or infiltration at these sites. The result is standing water which is not necessarily associated with the local groundwater table. Ponding can be identified by the local accumulation of rain or flood waters. It can be differentiated from high water table because no lag time is involved between precipitation and accumulation and because other sites susceptible to normal high water table may not possess standing water. Although water commonly moves fairly rapidly through sand, local soil development, surface or subsurface impermeable lenses (clays or bogs), or extremely high water table could reduce infiltration. These sites may contain marsh grasses and blue-gray mottled soils.

1. Potential sites

a. Foredune/deflation plain

Some special ponding problems may occur here which involve some degree of interaction between these two landforms. Many deflation plains contain valuable freshwater marshes. Any breaching of the foredune, whether natural or man induced, may allow flooding from ocean storms to reach the marsh. The addition of saltwater could have damaging effects on the freshwater habitat particularly if the breaching allows for frequent flooding. Furthermore, particularly severe ponding in the deflation plain may cause breaching of the foredune from the inland side. Breaching from the landward side may be caused by saturation, from hydrostatic pressure, or overflow at a lowspot in the foredune. This can lead to further erosion and limit the protective capacities of the foredune.

b. Interdune and other low lying sites

Any low lying site commonly susceptible to high groundwater may develop ponding problems when the water table is too high to allow infiltration of excess water. Also those interdune areas which possess soils, particularly marsh or bog soils which may contain clays and other relatively impervious materials, could develop ponding conditions.

c. Surface stable dune and older stable dune

These dunes are susceptible to the effects of ponding because they are often underlain by relatively impermeable iron bands or older buried soils. In addition to other ponding impacts, slope failure can occur in this landform particularly when saturated strata have been bisected.

2. Potential impacts and management techniques

In addition to many of the impacts resulting from a high water table, ponding can lead to serious flooding of surface structures and habitats. Damage to subdivisions in low-lying areas, airport runway safety hazards, slope failure and possible habitat degradation could result from ponding. Those activities which would dam waterways, alter drainage routes, compact the soil surface or otherwise significantly reduce infiltration rates (i.e. blacktopping) can increase the ponding hazard.

Proper design, engineering and building techniques can avoid many problems here. Large scale developments which could have wide ranging impacts, particularly if proposed for flat or low-lying areas, merit special attention. Landfills, septic tanks or other subsurface structures should not be permitted without a thorough engineering review. There is a high possiblity of contamination of surface and groundwaters from septic tank failure resulting from ponding. The use of dikes and levees to prevent flooding along riverways should be considered carefully as these devices can prevent the natural runoff of rain and floodwaters. The use of ditches, drain tiles, floodgates and building on pilings may improve the potential for development in such sites.

C. Saltwater Intrusion

The intrusion of saltwater into the groundwater occurs when the hydrostatic pressure (head) from fresh groundwater sources is insufficient to keep the marine water at bay. As already mentioned the position of the saltwater/freshwater interface is not known for all sites along the coast. Where it has been investigated under the larger dune sheets, the interface most commonly extends slightly seaward of the beach (Sweet, p. 12; U.S. Forest Service, 1972, p. 14; USGS, unpublished). It also appears to maintain a fairly vertical slope to some depth as even those exploratory wells behind the foredune have drawn no saltwater (U.S. Forest Service, p. 14).

Areas which do not capture enough precipitation to maintain sufficient head against the marine water may be underlain by saltwater. Because freshwater is less dense than saltwater, it may form a lens which overlies the saltwater in such sites. Sand spits, because they possess so little recharge area and are nearly surrounded by marine and brackish waters, may be potential sites for this groundwater pattern.

1. Potential sites

The sites most susceptible to saltwater intrusion are sand spits and the thinner beach and dune strips which possess more marginal water supplies. Although those spits underlain by sand to a considerable depth usually contain good groundwater supplies, the lack of recharge in the summer months when water is most in demand by summer residents could be potentially hazardous. The deeper, westernmost wells would be the first to experience saltwater intrusion. With overdevelopment of groundwater resources, saltwater could intrude some distance even into the dune sheet regions.

2. Potential impacts and management techniques

Overdevelopment of the groundwater resources could lead to encroachment of saltwater into this resource. The impacts of saltwater intrusion can result in permanent or temporary pollution of the freshwater supply, loss of freshwater dependent vegetation and habitat, corrosion of pumping facilities and the added cost of providing new water supplies to developed areas.

All dune areas for which groundwater withdrawal is being considered should have adequate hydrological studies conducted to determine the amount of groundwater required to provide protection against saltwater intrusion and any secondary effects. Some surveys have been produced for the major sandsheet areas along the Oregon coast and others are currently underway (see Appendix A).

Monitoring of the groundwater head and water quality at shoreline sites could provide prompt information on any changes in the freshwater/saltwater interface.

D. Drawdown

Drawdown is the resultant lowering of the water table level from well pumping. Given homogenous materials, the water table will drawdown in a cone shape surrounding the well or wells (see Figure 2). Extended development and pumping in an area can result in general lowering of the regional water table. The pattern of groundwater reduction is complicated in the deeper sands of the dune sheets because they are commonly interspersed with less permeable lenses of clay and silty materials. Groundwater at depth tends to flow seaward laterally through these lenses (see Figure 3). Thus pumping here may not lower the water table in the immediate vicinity but rather in an adjacent region up gradient.

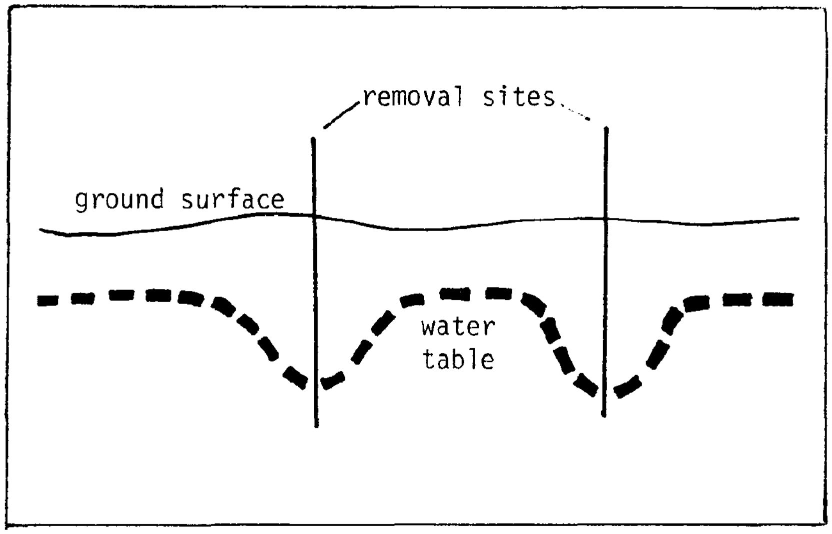

Figure 2. Generally, water withdrawn from the groundwater supply will result in cone-shaped depressions surrounding the removal site.

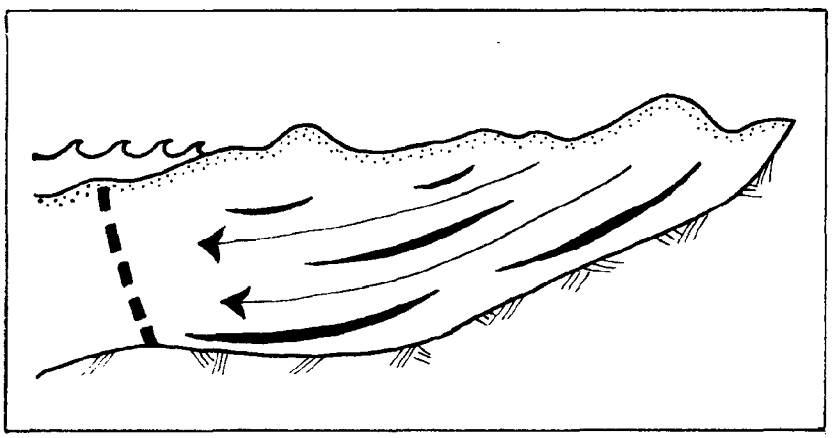

Figure 3. Impermeable lenses of clay and silty materials may direct the seaward flow of groundwater laterally.

1. Potential sites

Naturally all areas are potentially subject to drawdown. Critical areas would include recreational lakes, areas of stabilizing vegetation and those with little recharge.

2. Potential impacts and management techniques

The hydrological characteristics vary considerably from one site to another and therefore the potential impacts of a lowered water table also vary. Some potential impacts include the lowering of the water table below the depth of local wells, reduction of lake levels, draining of wetlands, loss of vegetation, seawater intrusion and intrusion of water of poor quality from underlying bedrock.

With advance planning most of these problems can be readily avoided. The proper spacing of wells to avoid overlap and regional lowering of the groundwater table can be calculated by hydrological studies. Wells should not be placed near those lakes most affected by lowering of the water table. Some dune lakes interact intimately with groundwater because this and direct precipitation are their only recharge sources and because they have highly permeable sand beds. Beale Lake and Sandpoint Lake in Coos County are examples of lakes underlain by less permeable sediments which slow down the rate of recharge from the lake back to the groundwater in the summer. Coffenbury Lake in Clatsop County and perhaps to a lesser extent Clear, Saunders and Butterfield Lakes in Coos County fit this category (Robison, 1973; Frank, 1970). These lakes may be partially fed by surface streams and runoff from hard rock areas bordering the sand dunes. Hyrological studies will provide critical background information for the safe and beneficial development of these areas.

E. Pollution

The pollution of groundwater involves the introduction of unwholesome or undesirable elements rendering the water unfit for use or environmentally degraded. Because sand dune aquifers experience particularly high infiltration rates, they are especially susceptible to pollution. Many fluid pollutants travel significant distances quickly in this sand medium.

1. Potential sites

Because the sand is highly porous and does not filter some types of harmful elements, all sand dune areas "downstream" from emission points of harmful substances should be considered potentially pollutable.

Those areas which should receive special consideration because of particular locational or high water table problems are:

a. All deflation plains and deflation plain fringes

This includes both the presently "active" deflation plain forms which are situated on the lee side of the foredune and historically active forms which are now found considerably inland from the present foredune area. These exhibit a flat surface topography, are usually forested and the water table is at or near the surface most of the year.

b. Lakes, streams and marshes

These bodies of water can be surface expressions of polluted groundwater. Conversely, polluted lakes, streams and marshes may affect local groundwater quality.

c. Near-beach sites

These areas may be occuped by temporary or permanent settlements and are major emptying points for the sand dune aquifer. Any non-filtered hazardous substances may appear here.

2. Potential impacts and management techniques

Bacteria have been shown to travel a maximum distance of only about 100 feet through similar sand aquifers (California Water Pollution Control Board, 1954, p. 99). However, sand is incapable of removing chemical contaminants. This includes those chemicals used in most household detergents which can render water unfit for domestic purposes. Some such contaminants not only produce a potential health hazard but may also threaten stabilizing vegetation.

Sand aquifers also appear incapable of filtering out viruses (Frank, p. 34). Outbreaks of hepatitis in some counties may be linked to septic tank problems in areas of high water table or ponding (Schlicker, 1974, p. 57).

Besides the naturally occurring sources of nitrate-nitrogen (NO_3-N) present in some areas of the sand dune groundwater, there also exist additional induced sources. Septic tank emissions and fertilizer used on pasture and croplands are significant sources in some areas (Sweet, p. 18). There are indications that excessive nitrate ingestion may cause methemoglobinemia (blue babies). The U.S. Public Health Service prohibits the use of water for drinking purposes if NO_3-N concentration is greater than 10 mg/liter (Sweet, 1977, p. 17). Furthermore, the U.S. Department of Environmental Quality has set a limit of 5 mg/liter in at least some sand aquifer areas on the Oregon coast (Berg, 1979). This is apparently due to seasonal population peaks and associated septic tank discharges (summer), natural seasonal peaks in the release of NO_3-N to the groundwater (winter), and high NO_3-N concentrations in some local organic soils (Sweet, p. 24).

There are a number of areas which use septic tanks and other private sewage-disposal systems which discharge into the sand. Some of these reportedly are sources of pollution to the area and others could become so (Frank, 1970, p. 34). The seriousness of the problem would depend on allowed density of development and the position of the waste discharges in relation to overall groundwater flow within the aquifer. Some experts feel that those operations which involve waste discharge, such as septic tanks and industrial lagoons, are not appropriate for sand areas under most conditions (Beaulieu, 1974, p. 30).

Local decision-makers and home owners alike will benefit from a better understanding of the potential benefits and hazards of the local groundwater regiem. Several studies have been conducted concerning water supply, quality, recharge and flow characteristics. A number of other studies are presently underway (Appendix A). Those state and federal agencies or local offices which may be contacted for further information include:

U.S.D.A., Soil Conservation Service
U.S.G.S., Water Resources Division
Oregon Department of Environmental Quality
County Sanitarian

The following references contain additional groundwater information:

Corcoran (1975)
Dugan (1976)
Hampton (1961 and 1963)
Smith (1962)

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APPENDIX A

Water Resource
Studies In Progress

WATER RESOURCE STUDIES IN PROGRESS

COUNTY	AGENCY	PURPOSE	STATUS
Clatsop	Clatsop County Planning Dept. and Oregon Dept. of Env. Quality (208 Water Quality-EPA)	A continuation of the Carrying Capacity of the Clatsop Plains Sand-Dune Aquifer (Sweet, 1977). Study will allow more in-depth research on the quality and quantity of the groundwater supply.	Approval recently granted
Lane	Lane County Environmental Health Division (Lane County Coastal Domestic Water Supply Report)	Study by Charles Strong (1979) identified available surface and groundwater supplies along coastal Lane County; focused on developed and developing areas.	To be released
Lane	Lane County Division of Environmental Health--North Florence Dunal Aquifer Study	Grew out of finding in Lane County Coastal Domestic Water Supply Report which identified potential groundwater problems in this rapidly developing area. Report will consider water supply, quality and potential groundwater hazards.	In progress
Douglas	U.S.G.S., Water Resources Division (LCDC)	Tests conducted at four wells in the deflation plain at about eighty feet deep. Both water quality and quantity are being researched.	In progress
Coos	Coos Bay Water Board/ (U.S.G.S. - WRD)	1. Dissolved Iron--study being conducted to determine the distribution of dissolved iron in the dunal aquifer. Series of test wells between Jordan Cove and Ten-mile Creek to aquifer bottom. Test samples to determine changes which take place in the location and concentration of dissolved iron and other chemicals as well as pumped.	In progress
		2. Extraction System--following the above study, when the best water sources have been identified, a groundwater extraction system will be designed which will allow water removal with the best possible benefits to users and the environment.	Planning stages
		3. Spit Water Supply Investigation--Research presently underway to determine the best possible way to develop the Coos Bay Spit's water supply to serve an industrial park system.	Planning stages